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More scientific news from chemical congress in Toronto

CALENDAR OF EVENTS
Scientific meetings Page 44

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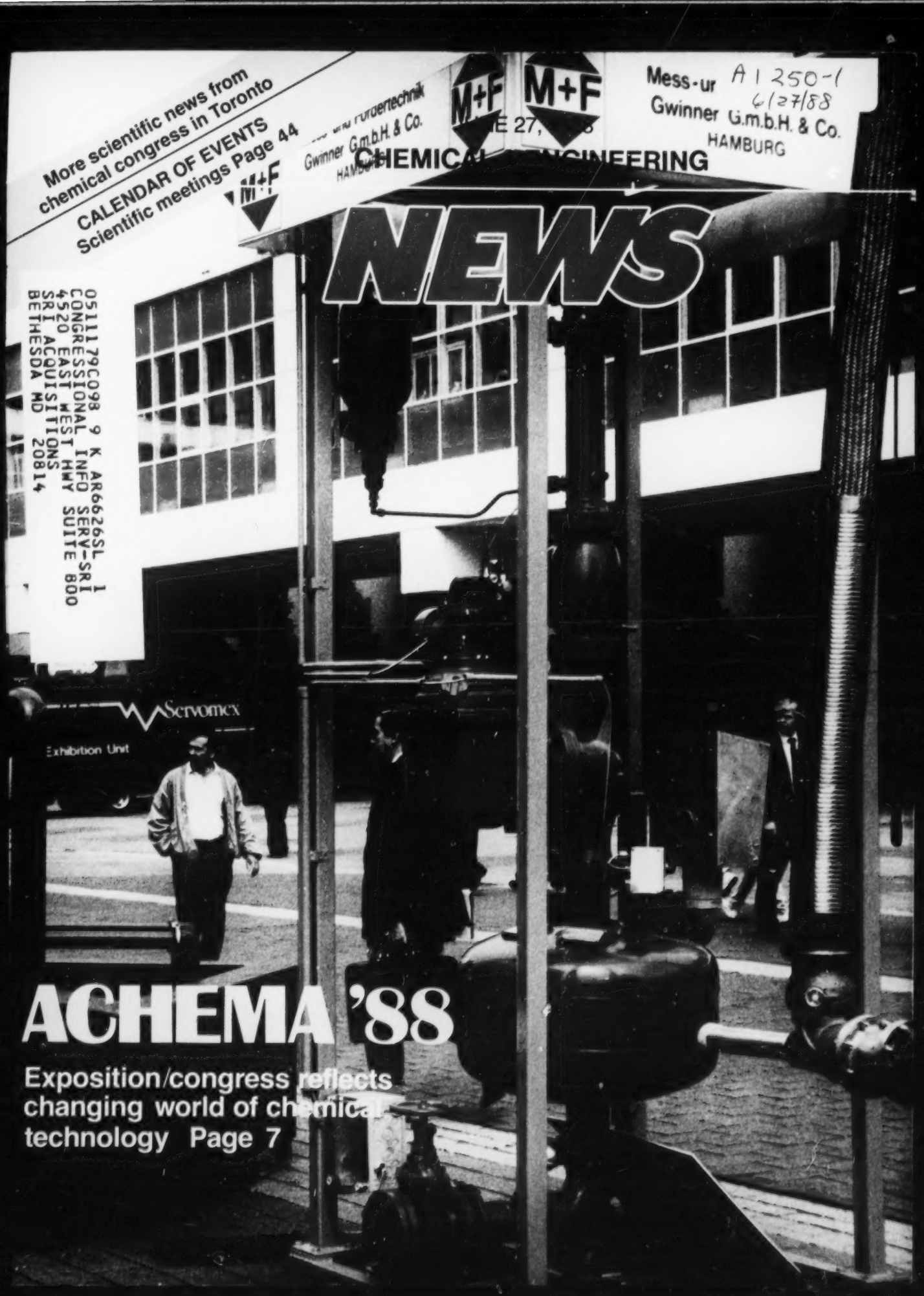

ACHEMA '88

Exposition/congress reflects changing world of chemical technology Page 7

CHEMICAL & ENGINEERING
NEWS

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JUNE 27, 1988

News of the Week

■ **Deciding to go outside India in its legal battle over the Bhopal disaster, Carbide has turned to a Connecticut state court.** **Page 4**

■ **The triennial plastics show, held in Chicago last week, set records for attendance, exhibit space.** **Page 5**

■ **Pennwalt is strenuously trying to head off a takeover bid by Centaur Partners, a group of New York City-based investors.** **Page 5**

■ **Office of Technology Assessment report spells out a number of ways for boosting the pool of science and engineering students.** **Page 6**

■ **European Community is making strong strides toward cutting CFC production and nitrogen oxides and sulfur dioxide emissions.** **Page 6**

Cover: Photo by C&EN's James H. Krieger

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Business

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Meetings

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News Focus

ACHEMA '88, the chemical engineering exposition and congress held in Frankfurt, West Germany, earlier this month, was a showcase for recent advances in process equipment and state-of-the-art chemical technology. **Page 7**

Chemical & Engineering News

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LETTERS

Tax burden

SIR: The letter from Pennsylvania State University graduate students Donald Cronce, Susan Ensel, and John Sczepanski (C&EN, April 25, page 3) regarding the 1986 Tax Reform Act prompted me to write of my own concerns in this matter. Last year, when learning that the new tax laws would make graduate student stipends taxable, my fellow students and I at Case Western Reserve University became very concerned over what this could do to higher education in the U.S. We were so concerned, that a letter was penned voicing these concerns and a copy, each individually signed by most of the graduate student population, sent to each of the Congressmen representing Ohio as well as Sen. Glenn and Sen. Metzenbaum. Of the very few responses we received from these gentlemen, most did not seem to realize what "situation" we were writing about, or simply said they "agreed" with us and "would support legislation" to correct the problem. It would seem that graduate students do not have a strong enough lobbying group to merit more attention from our elected officials.

As I have since received my degree, this problem no longer directly affects me, but, as a recent graduate, I can easily commiserate with my fellow students who now have to bear this tax burden. The long-term effects of this situation may be worse than most imagine. Not only will this pose a financial disincentive to those pursuing advanced degrees, the lack of a sufficient number of students will need to be corrected. Most likely this will involve colleges and universities being forced to look overseas in order to fill the demand. This will also create a deficit of American scientists and engineers, forcing industry to look elsewhere for qualified personnel as well.

Sheri L. Blystone
Oak Ridge National Laboratory

Interesting chemistry

SIR: The letter from David E. Henrie (C&EN, April 25, page 3) should be printed and reprinted until our innovators of freshman chemistry courses take note and realize what is happening.

I agree 100% with Henrie, and I believe that somewhere along the way we have lost touch with reality.

After reading his comments, I read further on to page 20, which told of the amazing life of Carl Marvel. As I was reading, I couldn't resist thinking of what would have happened if he hadn't taken that interesting course in chemistry.

His contributions to World War II technology, his 500 journal articles, his four books, and the 176 students who earned their Ph.Ds. under his tutelage—where would they all be if he had decided to be a farmer?

Why not make the freshman chemistry course interesting and informative instead of all of the theoretical mumble-jumble that will probably never be used? Why not make it so that the students who take these courses will desire to go on further and maybe develop enough interest to become outstanding chemists like Marvel?

But if they don't go any further, at least they will have learned some usable chemistry instead of just wasting their time and everyone else's.

Dan Lange
St. Louis, Mo.

Environmental health

SIR: The rambling discourse on the perils of modern environmentalism by Fred Tausch Jr. (C&EN, April 18, page 2) is, to say the least, disturbing and extremely misleading. As an individual concerned about this country's environmental health and natural resources, I believe it is necessary to provide a more balanced assessment of the current environmental state-of-affairs.

Tausch's comments reflect the frustrations felt by many Americans when confronted with the facts of pollution and other forms of environmental degradation. The first and most natural human reaction is to ask: Who is to blame? Tausch's answer is simple—the environmentalists. In his search for the perfect scapegoat, Tausch takes the path of least resistance by tapping a highly vocal and visible political community, raising the well-worn (and, in this context, irrelevant) spectre of socialism, and participating in a peculiarly American strain of knee-jerk conservatism. Unfortunately the roots of, and solutions to, our environmental problems are more subtle, complex, and interrelated than anyone ever imagined.

Tausch attempts to characterize environmentalists, all environmentalists, as rabid, regulators-gone-mad, without distinguishing the many ideas and philosophies such a diverse movement may embody. Indeed, this magazine itself could describe many of its readers as environmentalists: concerned individuals, angry at the despoilation of America's natural resources, who desire objective, innovative measures to alleviate

Canada's Chemical Industry To Benefit from Free Trade with U.S.

Trade agreement will help commodity chemicals, but certain segments of the industry, such as specialty chemicals, may face problems

Earl V. Anderson, C&EN New York

Toronto

The Canadian chemical industry is looking forward to doing business under the Canada-U.S. free trade agreement that is worming its way through the legislative process in both countries. But, although the Canadian chemical industry, on balance, likely will benefit from the agreement, some segments of the industry will benefit much more than others.

Some segments, says James E. Sigurdson, will be hurt by the pact, whereas still others will notice little change in the way they operate. Sigurdson, a partner in Law, Sigurdson & Associates, a consulting firm in Toronto, told a session on changing patterns in international trade and regulations just how he thinks free trade will affect the Canadian chemical industry.

Traditionally, that industry has run a chemical balance-of-trade deficit. But largely because of the world-scale petrochemical plants that have been built in Canada over the past decade, that deficit has been declining. Last year, Canada exported $3.78 billion (U.S. dollars) worth of chemicals and imported $4.84 billion worth.

However, among chemicals, Canada is a net exporter only in industrial chemicals. It runs a trade deficit in synthetic resins, for instance, despite its new, world-scale resins plants. Canada also remains a net importer of specialty chemicals and plastics.

The Canadian chemical industry, says Sigurdson, grew up behind a high tariff wall—part of the government's "infant industry" concept of tariff protection. "Several chemical areas still operate happily under that type of protection," he says. However, many petrochemicals and commodity inorganics now are internationally competitive. And on many of these products, there are no tariffs between the two countries.

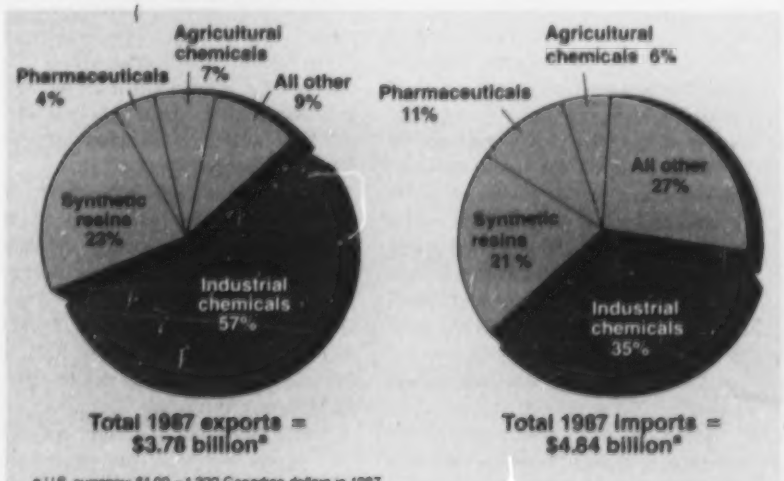
Although the free trade agreement will eliminate tariffs on chemicals over a period of five or 10 years, tariffs aren't really a factor for many chemicals in which Canada has a strong competitive position. Tariffs, Sigurdson says, are a factor only for the small, regional chemical producers in Canada.

He divides Canada's chemical businesses into two groups. One is chemicals that are produced in large, world-scale plants, are competitive, and require export markets to soak up output. The other group contains a variety of all other chemical and plastics products.

The impact of the free trade pact on Canada's fertilizer business will be slight to nil, Sigurdson says. That's because there now are no tariffs on Canadian fertilizer moving into the U.S. Canada produces about $2.7 billion worth of fertilizers and exports just over $1 billion of that output. About 10% of all Canadian chemical exports are fertilizer, and most of it—about 60%—goes to the U.S.

In his analysis of fertilizer trade, Sigurdson includes potash, which is Canada's largest fertilizer export. Official chemical trade figures from

Industrial chemicals account for most of Canadian chemical trade



* U.S. currency; $1.00 = 1.322 Canadian dollars in 1987.
Source: Law, Sigurdson & Associates

Statistics Canada do not include potash. The U.S. is the primary market for other fertilizer products, such as ammonia and nitrogen fertilizers. These products, which account for $378 million in exports, have been hurt for the past several years by the worldwide slump in fertilizers and low farm product prices.

Fertilizer trade, says Sigurdson, tends to be regional. Canadian fertilizer plants in Saskatchewan and Alberta are blessed with low-priced natural gas for their ammonia units. After meeting local demand on the Canadian prairies, producers export their product to the states immediately south of them.

Eastern Canadian fertilizer producers are much smaller and serve the regional markets of New York, Ohio, Pennsylvania, and Michigan. That, says Sigurdson, means that they do not have a market-access problem, although they are more sensitive to competition from other countries than their western counterparts.

Sigurdson also singles out a group of 24 "selected" commodity chemicals in which Canada has a solid competitive position. Substantial volumes of these chemicals are exported, both to the U.S. and to other world markets. They include petrochemicals, which benefit from Canada's inexpensive natural gas, and inorganics, which enjoy low power or raw material costs.

The combined exports of these 24 products add up to $1.6 billion, about half of which moves south of the border. Inorganics exports go primarily to the U.S. and tend to be regional. Organics are exported, not only to the U.S., but to the Pacific Rim and to Europe as well.

U.S. tariffs on these products range from zero to 20%. The higher tariffs are on organics (ethylene dichloride, 20%; methanol, 18%) and, in some cases, do distort trade, says Sigurdson.

However, only in a few instances does he expect the free trade agreement to cause a major shift in trade flow. The $862 million worth of these products exported to the U.S. last year involved duties of only $72 million. Sigurdson says that when the agreement removes these duties, Canadian ethylene dichloride, isopropyl alcohol, ethylene glycol, and a few others in this product group will be the prime beneficiaries.

Petrochemicals are the group's top performers and derive their strength from Alberta's world-scale petrochemical plants. From these plants, styrene, ethylene dichloride, and ethylene glycol are exported to the Pacific Rim countries and to the western U.S. Styrene and isopropyl alcohol are the primary export products of the eastern Canadian petrochemical producers.

Canadian producers of chlor-alkali, hydrogen peroxide, and sodium chlorate rely on Canada's favorable supply of electricity to be competitive on the continent. Virtually all of these products that are exported go to the U.S., although Sigurdson notes that some sodium chlorate is starting to move offshore.

Canada's inorganics already face little or no tariff barriers in the U.S. The free trade agreement likely will have little impact on them. The trade pattern of some organics could shift, Sigurdson says, as some styrene, methanol, ethylene dichloride, and ethylene glycol going to the Pacific Rim could be diverted to the U.S. market. However, the major impact of the agreement's tariff reductions will be to increase netbacks, particularly on products that now have high tariffs.

Analyzing the agreement's effect on Canada's polymers (plastics and rubbers) exports is more complex. Canada is a strong exporter of plastics resins and synthetic rubber. But it also processes and exports plastics products made from its own resins.

What the Canada-U.S. free trade agreement will do

The Canada-U.S. free trade agreement was signed by the two countries on Jan. 2, but the pact still must make its way through the legislative process of both countries. The target date for implementing the agreement is Jan. 1, 1989.

One of its major provisions calls for eliminating tariffs on trade between the two countries. Tariffs will be eliminated on all goods and services over a maximum period of 10 years. For those sectors that require no adjustment, tariffs will disappear on Jan. 1, 1989, if both countries agree to it. Those sectors that require some adjustment will see their tariffs disappear over a five-year or a 10-year period.

Generally, inorganic commodity chemicals, organic commodities, and synthetic resins fall into the five-year category. It likely will take 10 years to reduce tariffs on specialty chemicals, blended and mixed products, and on plastics products.

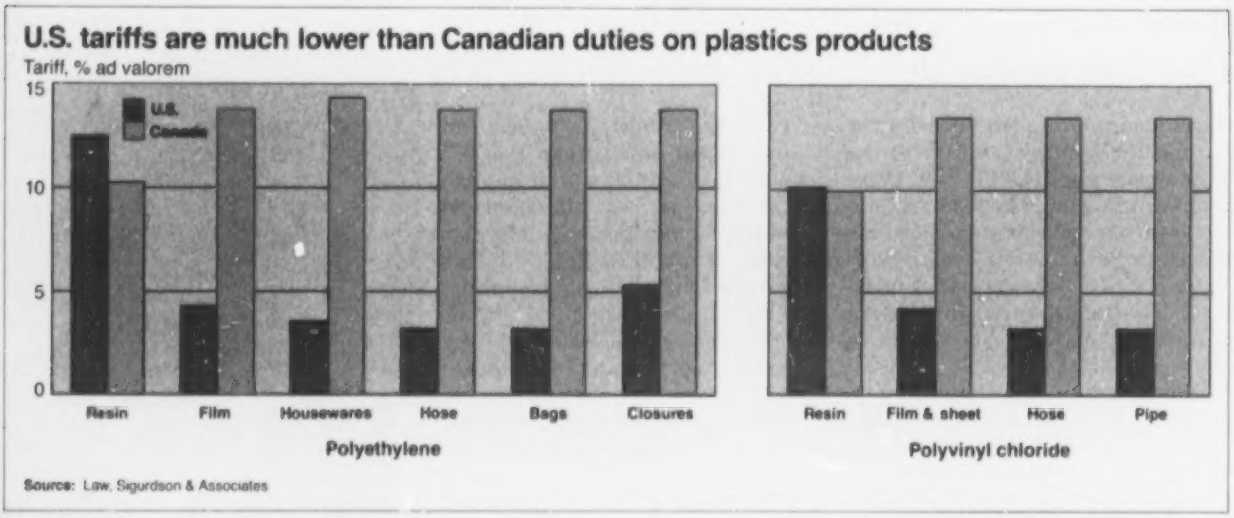
The reductions will occur evenly over the period. For instance, if tariffs were to be eliminated over a five-year period, they would be reduced 20% in each of those five years.

The agreement prohibits both countries from imposing restrictions on the volume or price of products crossing the common border. Another section contains rules of origin. These stipulate that products must contain a minimum of 50% North American (U.S. or Canadian) content in order for their tariffs to be eliminated.

Under the pact, Canada and the U.S. agree that technical regulations should not create unnecessary trade barriers. The two countries also agree to recognize each other's laboratory accreditation systems and eliminate duplication in product testing.

Energy is an important part of the agreement. The agreement prohibits imposing minimum export or import prices on energy. It prohibits imposing taxes on energy exports unless those same taxes are imposed in the domestic market. And it stipulates that any export restrictions must not disrupt normal supply channels.

The pact also covers trade in services. But one of its most contentious provisions calls for a bilateral panel to settle trade disputes between the two countries. Presumably, the panel will ensure that the two countries apply their antidumping and countervailing duty laws impartially.



Total exports of plastics resins and products ran about $1.21 billion last year. However, Canada imported $1.06 billion of resins and $980 million of plastic parts, giving the combined sector a trade deficit of $830 million.

Alberta's petrochemical plants export primarily polyethylene and polyvinyl chloride. Eastern Canadian producers export polyethylene, polypropylene, and Polysar's elastomers. The U.S. is Polysar's major export market for nitrile and butyl rubbers, Sigurdson says, but the other polymers are more oriented toward offshore markets.

Only modest volumes of polyethylene, polypropylene, PVC, and polystyrene are exported to the U.S. The major focus is the Pacific Rim and Europe. Some polypropylene even moves into South America.

At least part of the reason for this, Sigurdson says, are the tariffs facing Canadian polymers exported to the U.S. For the major thermoplastics, they are in the 10 to 12.5% range. Generally, rubber products face no tariffs. Consequently, Canadian rubber plants have, in effect, been part of the North American market for some time, he explains.

Obviously, free trade under the agreement will open up the U.S. market for Canadian thermoplastics. Removing the $27 million that Canadian producers pay in duties will help make them more competitive. And Sigurdson believes that the pact also will cause a significant shift in the export patterns of Canadian resins, with much more earmarked for the U.S.

The best example, Sigurdson says, is polypropylene. Shell Canada Chemical and Himont have a combined annual capacity of 206,000 metric tons of the polymer in eastern Canada. But they export little to the U.S. Removing U.S. tariffs on the polymer will make Canadian polypropylene much more competitive in the U.S.

What complicates the picture for this segment of the Canadian chemical industry is that U.S. tariffs on the major thermoplastic resins are greater than those on the converted products made from them. This has provided a major incentive for Canadian plastics processors to move product into the U.S. "Resin suppliers," Sigurdson says, "have been willing to help in the process," because its more advantageous for them to encourage product exports than try to export resin directly.

Exports of Canadian plastics products have been growing over the past few years, with more than 70% of them going to the U.S. But Canada still has a $430 million trade deficit in this sector, despite the 12 to 15% tariffs that protect Canadian plastics processors. U.S. tariffs on these products, by comparison, range from 3 to 6%.

The Canadian Society of the Plastics Industry has given the free trade agreement only a qualified endorsement, says Sigurdson, because of the "structural problems" facing many of its processor members. Many of them are small and, after operating behind high tariff walls, will face severe competition as Canadian tariff protection is removed under the agreement.

In addition, Sigurdson says, since Canadian resin producers will be able to export their product to the U.S. without duty, they will have less incentive to encourage exports of plastics products to the U.S. This will increase the difficulties likely to face Canadian processors under the agreement.

The net result will be that, over the 10-year phase-in period, Canada's strong, sophisticated processors will do extremely well in the northeastern North American market, says Sigurdson. The weaker ones will find the going tough. And, although Canadian resin exports to the U.S. could double under the free trade pact, the processors in Canada will be more on their own, he says.

Pharmaceuticals, specialty chemicals, paints, and surfactants also will face some tough times under the agreement. Their basic tariff protection will drop and, because their production is centered in eastern Canada, they will have to find market niches in the regional market of northeastern North America.

Sigurdson sees increased petrochemical investment in Alberta as a result of the agreement. There is still more ethane there that can be cracked into ethylene, he says. And as exports of downstream products to the U.S. increase under the pact, more ethylene will be required. □

Good year forecast for European chemicals

It was medium-to-good news for the European chemical industry at the annual meeting of CEFIC, the European Council of Chemical Manufacturers' Federations, earlier this month in Berlin. After a weak start to 1987, CEFIC reported, the recovery of chemicals output in Western Europe led to an overall growth of almost 4% for last year.

Domestic European demand was high, and most sectors experienced high capacity utilization. Production was particularly strong in basic petrochemicals, plastics, and consumer-related sectors, but fertilizers and fibers remained weak.

The outlook for 1988 is similarly reassuring. It is expected to be another good year for the chemical industry, with continued firm demand and high levels of production and capacity utilization. Output is forecast to grow some 2.5%, underpinned primarily by European domestic demand. However, the continued weak U.S. dollar will weaken European chemical exports, holding growth to only 4% in volume; imports are expected to grow 5.5%. Capital spending is expected to continue strong, growing at 6% in real terms.

With the industry's basic condition sound, that gives CEFIC a chance to continue addressing concerns such as environmental protection and health and safety, says Günter Metz, newly elected president of CEFIC and a vice president for West German chemicals producer Hoechst. These issues, he says, "remain the number one concern of CEFIC."

And it is not just a matter of technology: "We cannot just do things in a better way like producing safer products, using cleaner technology, reducing emissions, to mention a few," Metz says. "We must above all gain confidence of the population at large and take even more account of emotional reactions that are often due to ignorance of facts. In the past, we made the mistake not to explain clearly enough the rather complex chemical reactions that are not as transparent as the production process in other industries."

The second point for CEFIC's priority list will be, Metz adds, what this year has become the all-consuming topic in European business and political life: the "Single Europe Act," scheduled to go into force by 1992. The act will bring about uniformity and harmonization across a broad spectrum of physical, fiscal, and technical issues. It will also build a huge market of 320 million people.

"It is not the industry that is responsible for still-existing barriers," Metz says. "We want them to be removed. The concept of a Europeanwide integrated market fits very well with the philosophy of the chemical industry, which has always supported free trade with as little interference as possible. We should help create awareness and enthusiasm for this great move, so that the momentum becomes so strong that individual hurdles can no longer bring the process to a halt."

On the other hand, with the emergence of a single European market, warned Martin Bangemann, West Germany's minister for economics, there could be an attendant emergence of a "fortress Europe" concept. "I believe it would be wrong if the European Community were to grow together, just to protect itself from the outside," he says. "As we are living in a world growing together, we can't forget the rest: We have to become a fair trading partner for everyone. We are interwoven in the world economy."

Metz: Europewide integrated market

One of the major areas of harmonization will be in environmental standards. At a press conference following the meeting, a number of questions dealt with how these standards would be "harmonized" throughout Europe, the concern being that if the standards are not, then countries with more stringent standards will be at a competitive disadvantage to other countries.

However, according to Aarnout A. Loudon, past president of CEFIC and chairman of Akzo, of the Netherlands, "The chemical industry is often accused of wanting harmonization at the lowest levels," and that, he says, is not true. "At CEFIC, we want harmonization. We will accept high measures, but these will then be equal for all countries in the same level of economic development. We cannot ask for the same levels of environmental protection from countries less developed. We must give them time to build up, economically, so they will be able to afford the outlays."

Patricia Layman, London

Portugal led output growth in Europe last year

	% change 1986–87 in volume of chemical production
Portugal	14.9%
Sweden	8.7
Ireland	8.2
U.K.	7.4
Spain	7.0
Netherlands	6.9
Austria	5.6
Norway	4.4
Switzerland	3.2
France	3.1
West Germany	2.4
Italy	2.2
Finland	1.4
Belgium/Luxembourg	0.6
Denmark	−1.2
AVERAGE, WESTERN EUROPE	3.9%

Note: Comparisons should be made with caution, because countries' national statistics frequently differ in what is included. For example, some countries include synthetic fibers, plastics, and rubber, while others exclude them. Source: European Council of Chemical Manufacturers' Federations

Study Traces Most SO_2 Emissions To Burning of Moderate-Sulfur Coal

Department of Energy study says that power plant SO_2 emissions could be cut 50% by clean-coal technologies currently under development

Pamela S. Zurer, C&EN Washington

Toronto

Electric utilities burning moderate-sulfur coal—not those that use high-sulfur coal—are the major source of sulfur dioxide emissions implicated in acid rain, a study by the Department of Energy's Pittsburgh Energy Technology Center (PETC) concludes. These emissions could be cut in half without having to change coal sources or boilers if promising coal-cleaning technologies are successfully developed, the study finds.

The results of the acid rain control initiative study were presented by PETC chemist Dennis H. Finseth at a symposium on controlling emissions from coal combustion. The session was part of a three-day symposium on acid rain that included presentations on atmospheric sulfur species and the effects of acid deposition on soil, water, and materials, as well as strategies for controlling emissions of acid precursors.

"We need to know where sulfur dioxide is coming from—both the geographical origin and what combustion technology produces it," Finseth says. "Without that information it is hard to consider what kinds of control strategies might work."

Accordingly, the DOE researchers assembled information from several databases to create a profile of sulfur dioxide sources. They put together design information on all U.S. coal-fired electric utility boilers from utilities with a generating capacity of more than 50 MW. All together, 1166 units representing a generating capacity of 299 gigawatts—essentially all U.S. coal-burning plants—were identified.

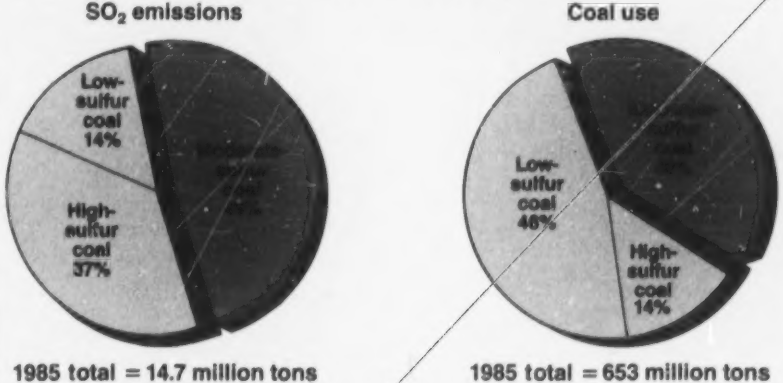
The PETC workers determined the amount, quality, and source of coal used by each boiler in 1985 and estimated the resulting emissions of sulfur dioxide. (The emissions were calculated by assuming that 95% of the sulfur in the coal is converted to sulfur dioxide.) They calculate the sum total of sulfur dioxide emitted in 1985 from electric utilities burning coal was 14.7 million tons, about 100 lb per U.S. resident, as Finseth points out.

The greatest portion of those emissions—7.1 million tons—came from plants burning coal that contains moderate amounts of sulfur—that is, about 0.75 to 2.5% sulfur. That surprising finding is in direct contrast to the generally accepted view that high-sulfur coals are responsible for most sulfur dioxide emissions. The PETC study indicates burning high-sulfur coal produced about 5.4 million tons of sulfur dioxide in 1985.

The researchers also looked at how the age and size of the utility boilers relate to sulfur dioxide emissions. The dominant sulfur dioxide producers, because they burn so much coal, are large plants with capacities greater than 600 MW. Most of these large-scale plants are less than 15 years old.

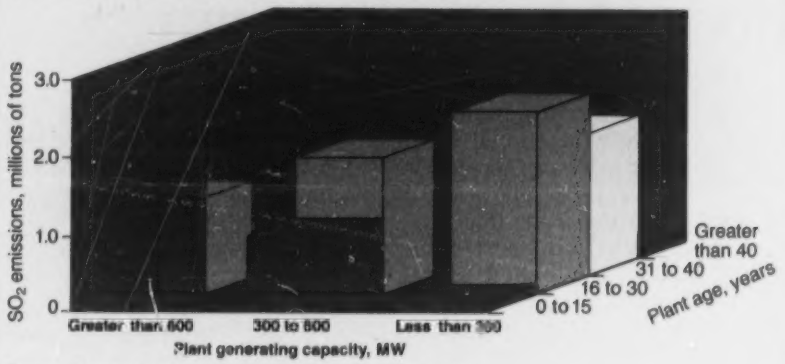
However, a significant portion of sulfur dioxide emissions come from smaller, older boilers that may be near the end of their economic lifetimes, Finseth notes. The diversity in size, age, and design of boilers that emit sulfur dioxide means that a wide range of strategies will be needed to control emissions.

Moderate-sulfur coal accounts for about half of SO_2 emissions, but only 40% of total coal use



Note: High-sulfur coal defined as yielding 4.0 lb or more of sulfur dioxide per million Btu; moderate-sulfur coal, 1.2 to 4.0 lb of sulfur dioxide per million Btu; and low-sulfur coal, 1.2 lb or less of sulfur dioxide per million Btu.
Source: Department of Energy's Pittsburgh Energy Technology Center

Older, smaller electric utility plants emit large amounts of sulfur dioxide



Source: Department of Energy's Pittsburgh Energy Technology Center

With the data on the origins of sulfur dioxide in hand, the DOE researchers examined possible ways to reduce emissions below 1.2 lb of sulfur dioxide per million Btu—a limit older plants may be forced to meet under some proposals for controlling acid rain. They selected two types of moderate-sulfur coal and two high-sulfur coals and investigated the cost and technical feasibility of reducing their sulfur contents by conventional and advanced cleaning methods.

"We tackled the issue by brainstorming," says Richard E. Hucko, acting director of the PETC advanced research division. "Which technologies could play a role and are far enough along in development and economically feasible?"

Advanced cleaning technologies alone could reduce emissions from moderate-sulfur coals to below the limit, the studies find. High-sulfur coals would require some type of flue-gas desulfurization in addition to coal cleaning to meet the standard.

All advanced coal preparation methods are ways of treating coal that has been ground very finely in order to liberate pyrite. (Most sulfur in coal is bound up in the mineral pyrite, iron sulfide.) "Grinding breaks the coal particles apart such that the coal may no longer be physically attached to the pyrite and they can be separated," Hucko says. Based on their technical capabilities and readiness for commercialization by 1992, three technologies were identified by the study as most promising for removing pyrite from coal: selective agglomeration, heavy-liquid cycloning, and advanced froth flotation.

In selective agglomeration, an aqueous suspension of the finely ground coal is mixed vigorously with a liquid that is immiscible in water. The hydrophobic coal particles mass together into large clumps in the organic phase. The mineral particles remain dispersed in the aqueous phase and can be separated from the coal material by screening.

Many of the initial studies of selective agglomeration used either chlorofluorocarbons (CFCs) or *n*-pentane as the organic liquid. The PETC team substituted *n*-heptane in its evaluation of the process, however, because CFCs are set to be regulated under the Montreal Protocol on Substances That Deplete the Ozone Layer and pentane would require explosion-proof process equipment.

Heavy-liquid cycloning takes advantage of the difference in specific gravity between coal and pyrite. A mixture of ground coal and a liquid with a specific gravity between 1.3 and 1.6 is spun in a cyclone. Centrifugal forces move the lighter coal particles toward the center and the heavier pyrite particles to the wall of the cyclone. The clean coal flows out the top and the impurities out the bottom. The PETC study used methylene chloride as the liquid in evaluating the technique.

Advanced froth flotation of coal is an improvement in coal flotation processes already used in commercial coal preparation plants. The study indicates that advanced processes that can separate ultrafine coal particles from pyrite require extremely small bubbles, new cell designs, materials that specifically depress pyrite, or some combination.

Any of the three advanced coal-cleaning technologies could reduce emissions from moderate-sulfur coals below the limit of 1.2 lb of sulfur dioxide per million Btu, Hucko notes. The study indicates the cost would only be about half that of limestone scrubbing of flue gases.

Coal cleaning alone would not remove enough sulfur to bring emissions from high-sulfur coals within the limit. However, advanced coal preparation, combined with treating flue gases by injecting lime into existing utility ducts could adequately reduce emissions, according to the study. The cost of using both methods together would still be less than conventional limestone scrubbing.

As a result of the study's conclusions, PETC has begun a program called the clean coal research initiative to try to advance the technologies identified as most promising. "Our major thrust is to bring the technology to a state of development where private firms could decide if they want to implement it," Hucko says.

Under the program, DOE has solicited and is considering proposals in two main areas. The first group focuses on understanding the surface properties of coal. "Pyrite often mimics coal, which is exactly what we don't want," Hucko says. "We need to try to understand once and for all at a scientific level how to get pyrite out of coal."

The second set of proposals deals with engineering development: how to design equipment and put together systems to implement the processes from grinding the coal on up.

Hucko says DOE expects to award funds for the clean coal research initiative by the end of the fiscal year. "We want to quickly gather data so that private firms can make decisions about using these technologies." □